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RESEARCH ARTICLE

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A longitudinal pre-post study: An evaluation of the Department of the Air Force bundled occupational fall prevention efforts

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Abstract

Introduction: Fall injuries are the second leading cause of traumatic injury and death for all US workers and are a leading injury concern for the Department of the Air Force (DAF). Bundled interventions can improve the likelihood of injury reduction, especially in large, heterogeneous working populations. In 2013, the DAF implemented the "Air Force Fall Prevention Focus," a bundled intervention of prevention efforts designed to reduce occupational fall injury events among DAF members. The purpose of this study is to describe the burden and risk factors associated with fall injuries and evaluate the effectiveness of the Fall Prevention Focus in reducing the burden of fall injuries.

Methods: The National Institute for Occupational Safety and Health (NIOSH) partnered with the US Air Force Safety Center (AFSEC) to examine the impact of the Fall Prevention Focus as a bundled intervention. Injury events included a narrative description of the injury event, demographics, work environment, job tasks, and other structured details. Descriptive statistics and pre–post longitudinal modeling were used to evaluate changes in fall injury rates.

Results: The Fall Prevention Focus Implementation (2013–2018) resulted in an annual 10.4% (95% confidence interval [CI]: 8.5%, 12.2%) reduction, and a 6-year cumulative 48.3% (95% CI: 41.4%, 54.3%) reduction in fall injury event rates by 2018.

Discussion: Safety in the DAF involves a comprehensive approach. Documenting the impact of the Fall Prevention Focus may help translate these findings to improve fall prevention efforts in other sectors of the military and high fall-risk industries in the private sector, such as construction.

KEYWORDS
intervention evaluation, military populations, occupational injury, occupational falls, occupational injury prevention

1 | INTRODUCTION

1.1 | Occupational fall injuries

Falls are among the top three leading causes of work-related fatalities, annually in the United States (US).[1] Nonfatal falls represent one of the most numerous work-related injuries[2] and cost an estimated $17 billion annually, representing 29% of work-related injury direct costs in 2019.[3] Falls are particularly severe for workers who perform tasks at heights, such as construction workers, maintenance workers, and workers who use ladders.[4,5] The construction industry experiences the highest annual number and rate of fall fatalities compared to all other sectors combined.[5,6] Falls to a lower level are the highest cause of traumatic injury death among construction workers, resulting in more than 300 deaths each year.[6] Over a million nonfatal injuries result in lost workdays for US construction workers every year.[6] Falls, particularly falls to a lower level, are a major risk factor for traumatic brain injuries in construction workers[7] as well as all US industries.[8] Similarly, falls are a leading cause of noncombat injuries among military personnel resulting in a significant loss of readiness,[9–12] even after excluding sport and recreation falls.[12] Situational fall protection is well documented to reduce injuries and injury severity; however, a review of fall prevention strategies reveals a shortage of multifaceted, effective programs in the literature, especially among military personnel.[13]

The National Campaign to Prevent Falls in Construction was launched in 2012 by the National Occupational Research Agenda (NORA) Construction Sector Council. NIOSH, OSHA, and the Center for Construction Research and Training (CPWR) lead the campaign to reduce fall injuries among construction workers.[14,15] The main messages of the National Campaign are for employers to: "Plan ahead so that worker safety is taken into account before a job begins; Provide workers the equipment they need to stay safe; and Train workers on how to use equipment safely." Beginning in 2013, the three agencies collaborated to host an annual stand-down with evidence-based communication about preventing falls in construction with millions of participants around the world, from a variety of industries, including the US Department of the Air Force (DAF).

1.2 | Bundled intervention

A bundled intervention with several elements of prevention methods may improve the probability of reduced injury rates, as each individual intervention may impact subpopulations differently. A single intervention applied across a larger working population may be less effective due to the homogeneous nature of a single intervention applied to a heterogenous population. "A *bundled intervention* is a group of evidence-based elements put together into a package that when implemented together produces better outcomes than when the elements are delivered separately."[17] This concept was first introduced by the Institute for Healthcare Improvement (IHI) in 2001 and has increased in popularity as a method of intervention deployment in clinical care, behavior change programs, and many other disciplines.[16–18] The World Health Organization recommends that interventions to be "interconnected, bundled, and tailored to the local context."[19] In this approach, the objective is not to measure an individual intervention component, instead to evaluate the combined effect of the bundled package. Although a bundled intervention may be designed to improve a specific outcome, the components could concurrently improve outcomes in other areas due to the robust nature of the elements bundled together. For example, a bundled intervention designed to improve fall injuries may concurrently reduce lifting injuries due to improved hazard analysis.

1.3 | Air force fall prevention focus, a bundled intervention

The mission of the Air Force Safety Center (AFSEC) is to prevent noncombat injuries and preserve combat capability by implementing prevention programs and promoting safety awareness across all DAF civilian and military personnel. Due to ongoing rates of fall injury events and the high severity of events, the DAF has prioritized fall injury prevention with agency-wide safety initiatives including participating in the annual National Safety Stand-down to prevent falls in Construction[14,20] and adapting a collection of efforts designed to reduce fall injury events as a result of the DAF implementation of the "Air Force Fall Prevention Focus (AFFPF)." Building on the National Campaign to Prevention Falls, the AFSEC created the Fall Prevention Focus starting in 2013, which designated 2 weeks each year to provide detailed information about fall prevention and safety. Across the DAF population including international bases, supervisors work with unit safety personnel to develop events such as a presentation, discussions, a guest speaker to highlight fall risks. Participants include active-duty Airmen, Guard, civilian workers, and leadership.

During those 2 weeks, the DAF units around the world actively participated in multi-component safety prevention efforts where workers and supervisors "stand-down" or pause to review fall hazards in their workplace and participate in fall prevention-related efforts. The particular efforts are worker-informed, vary by work tasks and safety needs of an individual unit, and include education, awareness, engagement, and activities. Some examples include reviewing current fall prevention policies; updating safety procedures or Job Hazard Analyses (JHA) with input from both workers and leadership; refining a safety training to include more hands-on components; improving consistency in work task language; developing innovative procedures to reduce fall risk (e.g., using drones for roof inspections rather than a ladder); collaborating with engineers to redesign tools and equipment (e.g., aircraft maintenance stands). The AFFPF supports the DAF Occupational Safety, Fire, and Health standards (AFI 91-203), which is required by the Air Force, but also the Occupational Safety and Health Administration. Relevant sections from this policy include: Chapter 7 (Walking–Working Surfaces) and Chapter 13 (Fall Protection), Chapter 16 (Mobile Elevating Work Platforms and Scaffolding), as well as potentially relevant parts of several other chapters (e.g., Chapter 17 on signage).[21] The AFFPF includes many resources to assist in fall prevention activities in a centralized location. The DAF Safety Center produces the Annual Fall Protection Field Guide to highlight fall protection activities throughout the DAF. Each year focuses on key safety guidance and real examples of safe work practices from DAF workers. Essentially, the AFFPF is a bundled intervention designed to reduce fall injuries among DAF personnel "considering the relevance, acceptability, feasibility, affordability, effectiveness and impact of the recommendation in the local context."[19]

The National Institute for Occupational Safety and Health (NIOSH) partnered with AFSEC to examine the impact of the AFFPF. Throughout this evaluation analysis, the AFFPF will be referred to as the "Bundled Fall Prevention Program" (BFPP). The purpose of this study is to describe the burden and risk factors associated with fall injuries in the DAF and to evaluate the effectiveness of the combined effect of the BFPP in reducing the burden of fall injuries, rather than an individual intervention component.

2 | METHODS

The AFSEC shared injury event data from 2008 to 2018 with NIOSH for collaborative analysis of injury events to estimate the reduction in noncombat, occupational falls attributable to the BFPP. The data were described by demographic and injury variables, and rates were calculated per 1000 workers. A longitudinal, retrospective, pre–post study was used to evaluate the change in fall injuries due to implementation of the BFPP beginning in 2013. The total study period included the years 2008–2018, where 2008–2012 is referred to as the pre-period and 2013–2018 as post-period. The pre-period included ongoing safety improvements as routinely implemented by the AFSEC across the DAF. The post-period included those ongoing safety improvements in addition to the BFPP. This activity was reviewed by CDC, deemed research not involving human subjects, and was conducted consistent with applicable federal law and CDC policy.[*]

2.1 | Data collection and definitions

2.1.1 | Population description

The study population included the entire enlisted, commissioned, and employed population of the DAF. Employment within the DAF is mainly comprised of active-duty military enlisted, military officer, and federal civilians.[22] Enlisted are more often in tactical positions and perform the more physically demanding jobs. Officers are more often in management positions. Active-duty military personnel often change locations every 2–3 years based on priorities and policies,[23] and are promoted out of physically demanding positions. By comparison, civilian workers are less geographically mobile, typically older than their military counterparts, and remain in physically demanding jobs. Contracted employees were not a focus of this study because injury reporting is the responsibility of contract employers.

The DAF Interactive Demographic Analysis System (IDEAS) is an internal, web-based application that provides accurate personnel demographics data for DAF members. Military demographics are updated weekly, and civilian demographics are updated monthly. The data represent the whole population of military and civilian workers, rather than a sample. To calculate fall injury events rates by occupation, occupation groups were matched between military and civilian workers based on tasks and reviewed for accuracy by a DAF human resources specialist.

2.1.2 | Microdata and variables

Before 2008, collection of safety events was not centralized and occurred at the unit level by safety professionals. Since 2008, the DAF has collected detailed information on all safety events among on-duty civilian workers and military workers (on- and off-duty) using the centralized Air Force Safety Automated System (AFSAS). Safety professionals are stationed at each base. Military safety personnel typically rotate every 2 years, while civilian safety personnel may continue in their positions for longer durations. Safety personnel communicate regularly with the AFSEC and receive recurring policy updates to accommodate the worldwide distribution of the DAF. Safety personnel are required to report and investigate every recordable injury event according to the DAF policies. The authors are unaware of any changes to these reporting requirements during the study timeframe from 2008 to 2018.[24] After a safety event occurs, onsite safety professionals collect information about the event circumstances and the injured worker, including information from medical reports. Information is entered into AFSAS, which allows detailed injury event information sharing DAF-wide for safety professionals. Quality control reviews are required locally at the Major Command level of the Air Force and again at the AFSEC Division level (including separate QC for Aviation and Occupational Safety, which would both be included in the AFSAS data for this analysis). A training manual with instructions for entering and retrieving data and AFSEC training courses are available to personnel and are frequently updated with improvements.[24] The deidentified data set used in this study included demographic variables (injured worker sex, age, occupation, personnel status (Enlisted, Officer, or Civilian), duty status) and injury variables (severity, days away from work, injured body part, injury mechanism, object associated with injury).

2.1.3 | Case definition and inclusion criteria for analysis

Noncombat safety events are defined as an incident involving an injury or property damage regardless of the person's duty status for military workers or for on-duty civilian workers. Severity is categorized according to one of five classes that are comparable to external injury reporting systems. During the period of this study, the most severe, a class A event includes a fatality, an injured person with 100% permanent disability, or over $2 million in damage; a class B event includes an injured person with permanent partial disability, or over $500,000 in damage; a class C event includes an injured person who missed at least 1 day of work, beyond the day of injury; a class D includes a person who received medical treatment beyond first aid; class E events include minor injuries and certain identified hazards. Class E events are not always required to be reported and do not always result in any injury.[24]

Injuries were categorized by injury mechanism, which is an AFSEC-internally developed three-tier categorical variable based on International Classification of Diseases, Ninth Revision (ICD-9), that first classifies events into 16 broad categories, and subsequently refines the definition of injury events. Falls were identified as one of the 16 broad categories (Tier 1), and subsequently classified into the type of fall by the Tier 2 of injury mechanism, including falls on the same level, falls to a lower level, and other types of falls (e.g., jump into water).

Severity classes A, B, C, or D were included. Injury events in this analysis included those categorized as aviation, ground, or motor vehicle. If an injury event involved an aircraft (e.g., during maintenance activities), then it may still be categorized as an "aviation" event. Injury events were excluded if they were related to combat, weapons, boating, swimming, or space activities. Although AFSAS captures off-duty events for military workers, this analysis included only on-duty events. AFSAS excludes events related to criminal activity, self-harm, or events involving worker dependents. The vast majority (99.8%) of fall injury events involved only one person, therefore we only examined information regarding the first person for injury events even if more than one person was involved in the event. Injuries involving contractors, military personnel from other branches and reserve personnel were excluded from analysis because the population counts were not available. For both descriptive statistics and modeling, a few cases of unknown age or unknown DAF personnel category ($n = 8$) were dropped.

2.2 | Statistical methods

2.2.1 | Descriptive statistics

Fall injury counts and percentages between fiscal years 2008–2018 were produced by sex, age, personnel status, and fiscal year to assess variability of falls across different demographics and time. Note that the DAF fiscal year starts in October of the previous year, for example, FY2013 started October 1, 2012 (Table 1). Percentages were also generated for different types of injury characteristics. A description of injury variables by type of fall was included in this study as exploratory, for future research comparisons, and for targeted prevention recommendations (Table 2). Injury variables provide different types of exposures or risk factors associated with fall injuries (e.g., Contact With Sharp Object, Non-Powered Hand Tool). Rates per 10,000 workers and rate ratios (RRs) were produced for demographics groups. Reference groups were chosen as those with the lowest rate and the largest population. Workers in the Air Force often perform similar duties regardless of their personnel status (military vs. civilian). Therefore, occupation groups were matched between military and civilian workers based on tasks and reviewed for accuracy by a DAF human resources specialist. This allowed calculation of annual rates by occupation group to understand risk of falls by overall burden (number of fall events) and the rate per 10,000 workers of fall events (Figure 2). All these were calculated with corresponding confidence intervals (CI) using SAS 9.4, PROC STDRATE, and PROC GENMOD procedures (Table 3).

2.2.2 | Design-adjusted statistical model for evaluation

The aggregate RR of fall injuries was evaluated using two approaches: (1) Overall aggregate change in pre- and post-periods without any adjustment (RR_{UnAdj}). (2) Yearly change in pre- and post-periods using fitted slopes and adjusting for covariates (RR_{Adj}).

2.2.3 | Unadjusted aggregate pre-post change

The overall observed aggregate RR between pre-periods and post-periods was calculated from the data based on the following formula (Equation 1). In this approach, data from the entire pre-period and entire post-period were aggregated to estimate the RR without any adjustment.

$$\begin{aligned}&\textit{Aggregate Rate Ratio Between Pre } (2008-2012)\\&\quad \textit{and Post } (2013-2018)\\&\quad = \left(\frac{\textit{Total Injury Between 2013 to 2018}}{\textit{Total Worker Population Between 2013 to 2018}}\right)\\&\quad \Big/ \left(\frac{\textit{Total Injury Between 2008 to 2012}}{\textit{Total Worker Population Between 2008 to 2012}}\right)\end{aligned} \tag{1}$$

2.2.4 | Adjusted aggregate yearly pre–post change

To adjust for the longitudinal effect (i.e., year-to-year fluctuation) and the covariates, a 2-slope longitudinal model was developed to evaluate how injury rates changed year-to-year during the pre-period (slope β_{pre}) and the post-period (slope β_{post}) after adjusting for gender, age category, and personnel category. The pre-period slope (β_{pre}) essentially implies the change due to ongoing safety improvements, while the post-period (slope β_{post}) implies the change due to both—the BFPP and the ongoing safety improvements. Adjusting for covariates essentially implies how much increase or decrease in injury rates is expected for a specific category compared to the reference category. The BFPP was not applied at the individual worker level but at the overall DAF population level, therefore the same workers were not followed over time in this prestudy and poststudy design. Based on the exploratory analysis, a factor-level combination of gender, age category, and DAF personnel category (e.g., male civilian workers in the <30 years old age group) showed a different count of falls due to imbalance in these covariates (Table 1). The following statistical model generated inference on the change of injury rates of pre- and post-periods after adjusting for the covariates and confounding (see Equation 2).

$$Log\ E(y_{ijkt}) = Log\left(\frac{\mu_{ijkt}}{N_{ijkt}}\right) = \beta_0 + \beta_i Gend_i + \beta_j AgeCat_j + \beta_k AFgroup_k + \beta_{pre} Time_{pre} + \beta_{post} Time_{post} \quad (2)$$

y_{ijkt} is the number of cases of injury in gender i, age category j, DAF personnel category k, and year t, *and* N_{ijkt} *is the corresponding DAF population (offset).*

μ_{ijkt} is the expectation of y_{ijkt} where $y_{ijkt} \sim Pois(\mu_{ijkt})$ or $y_{ijkt} \sim NB(\mu_{ijkt}, \theta)$ distribution; and $Log\left(\frac{\mu_{ijkt}}{N_{ijkt}}\right)$ is the logarithm of incidence RR of injury.

Longitudinal intervention (continuous)

$$\beta_{pre} = \textit{slope of the injury trend between } 2008 \textit{ to } 2012$$

$$\beta_{post} = \textit{slope of the injury trend between } 2013 \textit{ to } 2018$$

Year

$$t = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 \text{ timepoints (for 2008 to 2018)}$$

$$Time_{pre} = 1, 2, 3, 4, 5 \text{ timepoints (for 2008 to 2012)}$$

$$Time_{post} = 1, 2, 3, 4, 5, 6 \text{ timepoints (for 2013 to 2018)}$$

Demographic strata

$$i = 1, 2 \text{ gender}$$

$$j = 1, 2, 3, 4, 5 \text{ age categories}$$

$$k = 1, 2, 3 \text{ Air Force personnel categories}$$

Generalized Estimating Equations (GEE) were employed to adjust for the potential serial correlation[25] within each demographic stratum across time (2008–2018) for longitudinal data. Six GEE models were executed with Poisson and negative binomial link functions for count outcome data,[26] with repeated statement, under the covariance structures of autoregressive (AR1), compound symmetry (CS), and independent (IND). The parsimonious model (i.e., best-fitted model) was selected based on the lowest quasi-likelihood information criterion (QIC).[27] The negative binomial model with independent covariance structure (i.e., no evidence of serial correlation in residual) had the lowest QIC among the six GEE models. Hence, the final model was selected as the negative binomial model without any adjustment for serial correlation. All models were estimated using PROC GENMOD in SAS 9.4. Adjusted rate ratios (RR_{Adj}) were calculated by exponentiating the model coefficient (e^{β}); and the percentage increase or decrease were calculated by subtracting 1 from the RR_{Adj} then multiplying by 100, that is, $(e^{\beta} - 1) \times 100$.

Since the pre-period (2008–2012) slope is a measure of ongoing safety improvements while the post-period (2013–2018) slope is a measure of BFPP and the ongoing safety improvements, the unique BFPP contribution of the RR was estimated by subtracting the pre-period slope (β_{pre}) from the post-period slope (β_{post}) (see Equation 3).

$$\text{Estimated BFPP Contribution of Rate Ratio} = e^{(\beta_{post} - \beta_{pre}) \times Time_{post}} \quad (3)$$

3 | RESULTS

From 2008 to 2018, there were a total of 95,805 injury events recorded in AFSAS in a deidentified data set. Of these, 4900 were excluded due to zero injury cost, which indicated an event involving property damage rather than injury events. Another 15,982 injury events were excluded among reserve, contract, other military agencies, and other/unknown personnel types. Weapons-related military-specific events (n = 109), off-duty injury events (n = 15,238), and events with an unknown worker age (n = 8) were also excluded. A final count of 59,568 on-duty injury events involving at least one injury requiring medical attention were included in this study. For all injury events, the most common on-duty injury mechanisms involved objects (19,778, 33.2%), overexertion (11,835, 19.9%), falls (9,522, 16.0%), and sports (8,544, 14.3%).

3.1 | Descriptive statistics of injury events

3.1.1 | Descriptive statistics of population and fall injury events

Table 1 describes the numbers of workers, the numbers of injuries, and percentages of injury events for each type of injury. Enlisted military workers represented the largest number of workers and had the largest number of non-fall injuries. By comparison, the highest proportion of fall-related injury events were reported for Civilian workers. Annually, the number of workers overall remained stable, but both the number of non-fall injuries (−23.9%), falls on the same level (−47.2%), and falls to a lower level (−44.5%) decreased. The number and rate of all fall injuries combined consistently decreased during the 11-year period from 22.0 fall injuries per 10,000 workers in 2008 to 11.5 per 10,000 workers in 2018 (Figure 1).

TABLE 1 Demographic and work characteristics by type of injury event—US Air Force, 2008–2018.

	Worker population (2008–2018)		Injury events without a fall		Falls on the same level		Falls to a lower level	
	Number	%	Number	%	Number	%	Number	%
All injury events (*N* = 59,568)[a]	5,219,135	100%	50,046	84.0%	6440	10.8%	3048	5.1%
Sex								
Men	4,024,396	77.1%	41,863	83.7%	4297	66.7%	2164	71.0%
Women	1,194,739	22.9%	8183	16.4%	2143	33.3%	884	29.0%
Age group								
<30 years	2,167,325	41.5%	28,592	57.1%	2376	36.9%	1262	41.4%
30–39 years	1,388,502	26.6%	10,869	21.7%	1187	18.4%	581	19.1%
40–49 years	835,731	16.0%	5462	10.9%	1041	16.2%	470	15.4%
50–59 years	637,040	12.2%	4135	8.3%	1332	20.7%	542	17.8%
60+ years	190,537	3.7%	988	2.0%	504	7.8%	193	6.3%
Personnel status								
Enlisted	2,839,787	54.4%	32,215	64.4%	2,835	44.0%	1388	45.5%
Officer	696,859	13.4%	3102	6.2%	289	4.5%	151	5.0%
Civilian	1,682,849	32.2%	14,729	29.4%	3316	51.5%	1509	49.5%
Fiscal year								
2008	461,943	8.9%	4642	9.3%	669	10.4%	348	11.4%
2009	475,323	9.1%	5057	10.1%	643	10.0%	373	12.2%
2010	487,358	9.3%	5429	10.9%	767	11.9%	359	11.8%
2011	492,259	9.4%	5470	10.9%	762	11.8%	368	12.1%
2012	485,946	9.3%	5312	10.6%	636	9.9%	330	10.8%
2013	480,475	9.2%	4908	9.8%	621	9.6%	292	9.6%
2014	462,496	8.9%	4178	8.4%	604	9.4%	227	7.5%
2015	458,436	8.8%	4061	8.1%	504	7.8%	198	6.5%
2016	466,649	8.9%	3827	7.7%	437	6.8%	178	5.8%
2017	471,325	9.0%	3631	7.3%	444	6.9%	182	6.0%
2018	476,925	9.1%	3531	7.1%	353	5.5%	193	6.3%

[a]Includes 34 fall injuries classified as "other/unknown" that are not presented in the table.

3.1.2 | Descriptive statistics of injury events by type of fall

Table 2 examines injury events in more detail by severity (days away from work and severity class), injury mechanism, and object involved in the injury. Both falls on the same level and falls to a lower level had a significantly higher mean days away from work compared to all other injury events (Table 2). Similarly, both types of falls were classified as class C in higher proportions compared to all other injury events. Very few injuries related to falls were classified as class A or B severity (<0.1%). Most falls on the same level were related to the injury mechanism of a slip, trip, stumble (68.8%), or same level caused by ice or snow (27.3%). Most objects associated with falls on the same level included Miscellaneous (29.9%) and Roadway/Roadway Components (18.2%). The most common injury mechanisms among falls to a lower level included Slip, Trip, Fall From/On Stairs, Steps, or Curb (48.8%) and Fall On/From Ladder or Scaffolding/Stands (19.1%) with the most common objects associated with Aircraft (26.8%)

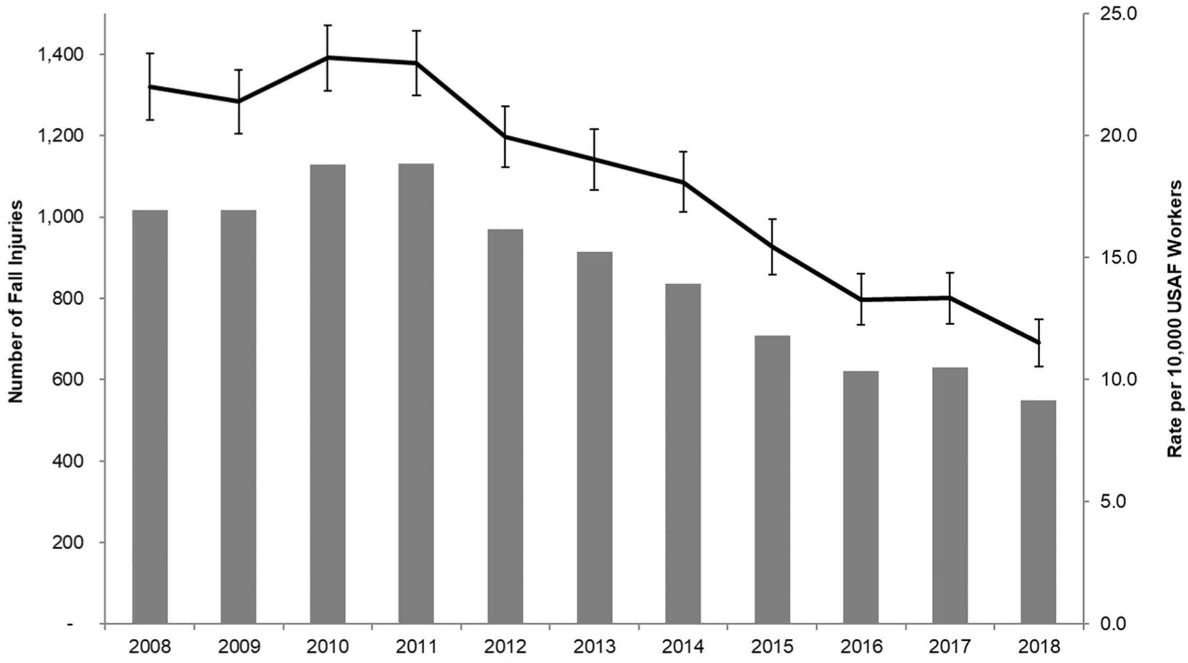

FIGURE 1 Number and rate of on-duty fall injuries—US Air Force, 2008–2018.

Buildings and Structure Components (24.9%). In contrast, all other injury types had more variety in the types of injury mechanisms, including: Striking Against Objects (12.6%), Strenuous Movements (12.5%), and Contact With Sharp Object (9.5%); as well as more variety in the objects associated with injuries: Miscellaneous (26.0%), Aircraft (20.0%), and Tools and Machines (11.8%).

3.1.3 | Descriptive statistics of fall injury events by occupation

Separately, we examined the number of fall injuries (Figure 2A) and the rate of fall injuries per 10,000 workers (Figure 2B). Aircraft maintenance workers consistently had the highest number of fall injuries, followed by law enforcement, safety, and investigations occupations, and engineering and construction occupations. However, metal work occupations had the highest rates of fall injuries compared to all other occupational groups (Figure 2B). The next highest rates were among maintenance occupations and aircraft occupations. Both numbers and rates of fall injuries trended downward for all occupational groups.

3.2 | Evaluation of bunded fall prevention program

3.2.1 | Inference on demographics

Model adjusted rate ratios indicated, compared to the age group 30–39 years (reference group), the age group <30 years has an expected 1.32 times (32.2%) more incidence rate of falls, the age group 50–59 years has an expected 1.36 times (35.9%) more incidence rate of falls, and the age group 60+ years has an expected 1.69 times (69.2%) more incidence rate of falls with the remaining predictor values held constant (at the reference level). The age group 40–49 years has about the same incidence rate of falls as the reference group (30–39 years, Table 3). Females had an expected 1.45 times more (44.5%) incidence rate of falls compared to males (reference group) with the remaining predictor values held constant. Compared to the Officer personnel category (reference group), the Enlisted personnel had an expected 1.99 times (98.9%) more incidence rate of falls, and the Civilian personnel had an expected 3.87 times (286.6%) more incidence rate of falls with the remaining predictor values held constant. See Table 3 for all confidence intervals.

3.2.2 | Aggregate change of pre-post-period (RR_{UnAdj})

The overall aggregate RR (using Equation 1) between pre (2008–2012) and the post (2013–2018) period indicated a 31.0% (95% CI: 28.2%, 33.8%) decrease in falls. This observed aggregate RR does not account for the longitudinal year-to-year fluctuations within a pre-period or the post-period, or for the imbalance in covariate groups.

3.2.3 | Inference on pre-post-period (RR_{Adj})

The longitudinal 2-slope model estimated a nonsignificant decreasing trend (slope) of 0.7% per year ($p = 0.6097$) for the pre-period (2008–2012), and a significant decreasing trend (slope) of 11.0% per year ($p < 0.0001$) for the post-period (2013–2018). After

TABLE 2 Injury characteristics by type of Fall Injury Event—US Air Force, 2008–2018.

	Injury events without a fall		Falls on the same level		Falls to a lower level	
DAFW[a] (Mean (95% CI))						
	7.9 (95% CI 7.6–8.2)		**12.1** (95% CI 11.2–13.0)		**12.3** (95% CI 11.0–13.6)	
Injury severity						
Class A + B	161	0.3%	–	–	4	0.1%
Class C	10,090	20.1%	2225	34.5%	1077	35.3%
Class D	39,869	79.6%	4224	65.5%	1967	64.5%
Injury mechanism associated with injury event						
	Striking against objects	12.6%	Same level—slip, trip, stumble	68.8%	Slip, Trip, Fall From/On Stairs, Steps, or Curb	48.8%
	Strenuous movements	12.5%	Same level caused by ice or snow	27.3%	Fall On/From Ladder or Scaffolding/Stands	19.1%
	Contact with sharp object	9.5%	Same level due to collision with/ push by, other person	3.9%	From one level to another (excluding more specific causes below)	14.6%
	Struck by object	8.4%			Fall involving chair	6.2%
	Lifting, handling, or carrying	7.3%			Fall from aircraft surface or fuselage/ cargo hold	4.5%
	Jogging/running	6.8%			Fall from, out of, or through building or structure (excludes falls from balcony)	1.9%
	Caught, crushed, jammed, or pinched in/between objects	6.3%			Fell off pole, usually utility	1.5%
	Basketball	4.4%			Fall involving other furniture	1.3%
	Nonpowered hand tool	2.7%			Fall from edge	1.0%
	Repetitive movements	2.5%				
	Football, flag/touch	2.2%				
	Exercising/calisthenics	2.0%				
Objects associated with injury event						
	Miscellaneous	26.0%	Miscellaneous	29.9%	Aircraft	26.8%
	Aircraft	20.0%	Roadway/roadway components	18.2%	Buildings and structure components	24.9%
	Tools and machines	11.8%	Buildings and structure components	14.4%	Miscellaneous	15.5%
	Vehicles	6.3%	Aircraft	8.7%	Furnishings/appliances	8.1%
	Buildings and structure components	4.6%	Vehicles	4.8%	Nonpowered AGE	5.8%
	Aircraft/RPA component	4.5%	Furnishings/appliances	3.5%	Roadway/roadway components	4.6%
	Containers	4.4%	Tools and machines	3.2%	Vehicles	4.2%
	Furnishings/appliances	4.2%	Containers	2.8%	Buildings and structures	3.3%
	Nonpowered AGE	3.1%	Construction/building materials	2.5%	Containers	1.0%
	Construction/building materials	2.6%	Nonpowered AGE	2.0%	Aircraft/RPA component	0.9%
	Powered AGE	1.8%	Powered AGE	1.8%	Construction/building materials	0.9%
	Animals	1.7%	Airfield/airfield components	1.2%	Towed equipment	0.9%
	Vehicle components	1.5%			Tools and machines	0.9%
	Roadway/roadway components	1.3%			Vehicle components	0.6%
					Electrical/communications equipment	0.3%

[a]Days Away From Work (DAFW). Class C only, excludes injury events with 0 DAFW.

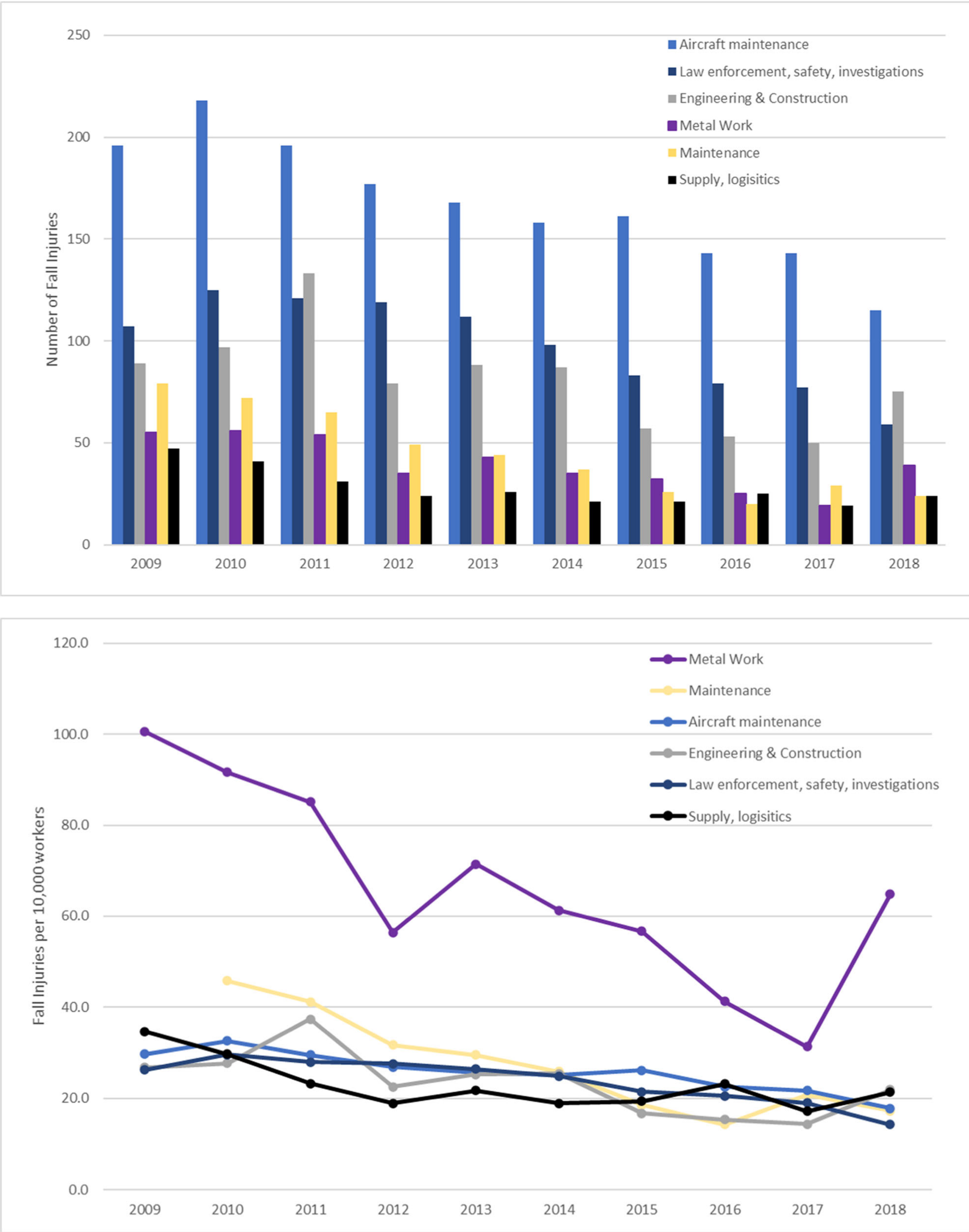

FIGURE 2 Number (A) and rate (B) of Fall Injury events by occupation group, US Air Force, 2009–2018.

TABLE 3 Observed (unadjusted) rates, rate ratios, and pre-post model adjusted rate ratios of on-duty fall injuries by age, gender, and personnel status—US Air Force, 2008–2018.

	Rate per 10,000 workers (95% CI)	Observed (unadjusted) rate ratio (95% CI)	Pre-post and covariate adjusted[a] rate ratio (95% CI)
Male	16.1 (15.7, 16.5)	Ref	Ref
Female	25.4 (24.5, 26.3)	1.57 (1.51, 1.64)	1.45 (1.34, 1.56)
<30 years	16.9 (16.3, 17.4)	1.32 (1.25, 1.40)	1.32 (1.20, 1.46)
30–39 years	12.8 (12.2, 13.4)	Ref	Ref
40–49 years	18.1 (17.2, 19.0)	1.42 (1.32, 1.52)	1.00 (0.90, 1.12)
50–59 years	29.4 (28.1, 30.8)	2.30 (2.16, 2.46)	1.36 (1.20, 1.54)
60+ years	36.6 (33.9, 39.3)	2.86 (2.62, 3.13)	1.69 (1.47, 1.95)
Officer	6.4 (5.8, 7.0)	Ref	Ref
Enlisted	15.0 (14.5, 15.4)	2.35 (2.13, 2.59)	1.99 (1.76, 2.25)
Civilian	28.7 (27.9, 29.5)	4.50 (4.09, 4.96)	3.87 (3.41, 4.38)
Slope (year-to-year)			
Pre (2008–2012)	–	–	0.993 (0.966, 1.020)
Post (2013–2018)	–	–	0.890 (0.869, 0.911)
Diff (Post-Pre)	–	–	0.896 (0.878, 0.915)

[a]Adjusted by gender, age, and Air Force Personnel Group.

subtracting for the ongoing safety improvements of the pre-period from the post-period (Equation 3), the estimated BFPP contribution showed a significant decreasing trend (slope) of 10.4% per year ($p < 0.0001$). This BFPP contribution of a yearly 10.4% decrease resulted in a cumulative 48.3% (95% CI: 41.4%, 54.3%) total reduction within this 6-year post-period.

Figure 3 displays the year-to-year change in slope (β), converted into RR and then into percentage change. The small circles are the cumulative year-to-year rate ratios observed from the data. Table 4 aids Figure 3 by describing the cumulative estimate of the intervention RR (difference between slopes of post-periods and the pre-periods) and the corresponding percentage decrease for years 1 to 6. In summary, the rate of fall injury events was 48.3% lower than expected in 2018 due to the implementation of the BFPP (Table 4).

4 | DISCUSSION

4.1 | Summary of findings

Safety in the DAF involves a comprehensive approach as represented by the AFFPF. The collective safety countermeasures incorporate ongoing updates to policies, procedures, and activities, with adaptations to worker tasks and geographic conditions. Some themes emerged from the AFFPF, such as always including a "wing man," the importance of hazard communication and reporting at all personnel levels and using prevention countermeasures from all aspects of the hierarchy of controls. This includes hazard removal, engineering controls, training, and personal protective equipment usage. All injury events, particularly falls, decreased among DAF both military and civilian workers from 2008 to 2018. When examining fall injuries by occupational groups, all rates trended downward during the period even after adjusting for gender, age, and personnel categories. Implementation of the AFFPF in the post-period (2013–2018) resulted in a 6-year cumulative, year-to-year 48.3% (95% CI: 41.4%, 54.3%) reduction in the rate of fall injuries.

The findings of this study can be adapted to workers in industries with high burden of fall injuries and fatalities, such as construction. Similar to our findings in DAF workers, Scott and colleagues found that injuries due to falls on the same level occurred more often to women and workers in older age groups.[28] The construction industry experiences the most fatal work-related falls compared to any other private US-industry.[4,10] Private sector employers may draw from the DAF Fall Prevention resources to improve safety programs and reduce injuries involving falls. Engineering controls might also focus on employer-provided footwear,[29,30] which has been shown to support reductions in falls as part of a comprehensive safety program. Other efforts should include continued focus on leadership and safety communication, which is a common safety intervention in construction.[31]

TABLE 4 Estimates of Bundled Fall Prevention Program (BFPP) contribution of the post-period (2013–2018) after adjusting for the ongoing safety improvements of the pre-period (2008–2012)—US Air Force, 2008–2018.

Year	$Time_{post}$	Cumulative rate ratio due to BFPP after adjusting for pre-period trend (95% CI) $e^{(\beta_{post}-\beta_{pre})\times Time_{post}}$	Cumulative percent decrease due to BFPP (95% CI)
2013	1	0.896 (0.878, 0.915)	−10.4 (−12.2, −8.5)
2014	2	0.803 (0.770, 0.837)	−19.7 (−23.0, −16.3)
2015	3	0.719 (0.676, 0.766)	−28.1 (−32.4, −23.4)
2016	4	0.645 (0.593, 0.700)	−35.5 (−40.7, −30.0)
2017	5	0.578 (0.521, 0.641)	−42.3 (−47.9, −35.9)
2018	6	0.517 (0.457, 0.586)	−48.3 (−54.3, −41.4)

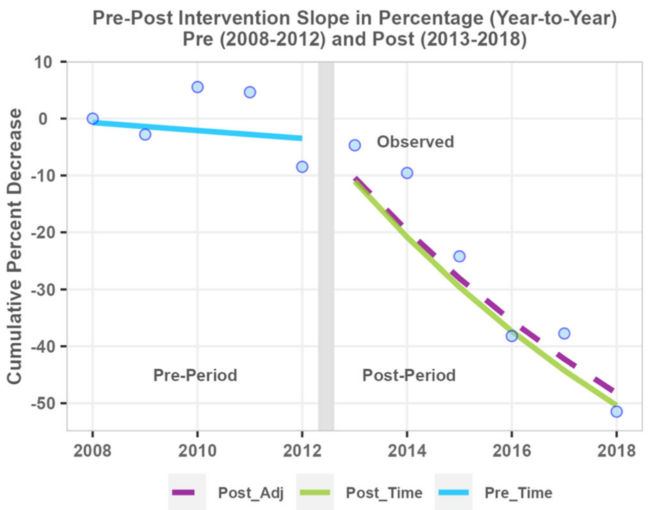

FIGURE 3 Percent decrease in All Fall Injuries during the pre-period (2008–2012, blue solid line), during the post-period (2013–2018, green solid line), and after adjusting for the pre-period ongoing safety improvements trend (purple dashed line). The small circles are the cumulative year-to-year rate ratios observed from the data.

4.2 | Strengths and limitations

An important strength of this study is the ongoing AFSAS surveillance system. Other studies in military populations have relied on limited safety information from medical records,[9,32,33] however AFSAS injury reports include more detail than medical records, such as injury mechanism, work task/activity, injured worker job series for both military and civilian workers, and event narrative. Other military branches rely solely on medical records to understand changes in injury patterns over time. Medical records are vital to describe the overall picture of injuries and health of services members.[34] AFSAS only captures those injury events that occur within the scope of work-related activities which represents substantially fewer injuries compared to those captured by service member medical records. However, work-related injury events are particularly relevant for formulating prevention efforts during work tasks. Medical records may be limited in their ability to detect granular changes in injury rates by occupational group and access may be limited to safety professional directly implementing local safety programs. AFSEC should continue to utilize the AFSAS system, which was recently expanded to the Department of the Navy and may also be utilized by other military branches. AFSAS reports include structured, hierarchical variables that are input and coded by safety professionals during injury event investigations. This system provides more information to guide prevention efforts. With any injury-reporting surveillance system, we may be missing a few injuries due to misclassification or underreporting. However, the Air Force is minimizing this by requiring several levels of review and quality control for each reported injury event. We wouldn't expect underreporting to change over time because the reporting requirements and methods have remained the same, therefore the downward trends should not be affected by misclassification or underreporting. Injuries may also be captured in AFSAS that were not recorded in DoD medical facilities, such as minor injuries that required days away from work.

Our analysis benefits from a comparison of fall injuries to non-fall injuries. We also show that falls to a lower level decreased more during the time period compared to falls on the same level. This difference revealed the positive safety impact on the BFPP, which was most pronounced in falls to a lower level. Another benefit is the inclusion of both injury counts and rates for understanding changes in fall injury events over time, even among different occupation groups (Figure 2A,B).

This study includes some limitations. We excluded events that did not involve an injury. Events that involved property damage were recorded in AFSAS and future studies may include noninjury events to examine cost effectiveness of prevention efforts. Errors in injury type categorization are certainly possible, but we wouldn't expect that to change over time. On the contrary, we would expect more injury events to be categorized as a fall over time rather than "other" as the system became more familiar to safety professionals. Furthermore, controlling the extraneous variables is another challenge that could potentially influence any study outcome.[35] Another limitation is the years of data in this study stopped at 2018. Future analyses might also include more recent years of data and comparisons of injury events before and after the COVID-19 pandemic.

AFSAS does not capture certain demographic information, such as race or ethnicity, which may be helpful to identify any gaps in equity surrounding work-related injuries. Due to jurisdictional restrictions, injuries among contract workers are not systematically captured in AFSAS because they are not employed by the DAF. Generally, reserve, contractors, and other workers would benefit similarly from prevention efforts given the close proximity of work. Another limitation of this study is that we could not examine the efficacy of individual interventions, but rather the impact of the overall BFPP. However, given the size of the organization and the variability of worker safety needs, it is impractical to examine each individual component's contribution to safety. Instead, we were able to globally assess the effectiveness of the comprehensive effort. The strength of the AFFPF is in the comprehensive collective effort, rather than discrete initiatives. Another strength of this study is that it evaluates how the intervention deployment works when applied to a large-scale DAF population level instead of a DAF sample level. Walsh et al., suggests "Population-level [intervention] approaches have large potential effectiveness, economic, sustainability, and equity benefits over individual-level approaches," since it targets the risk profile of an entire community or sub-population instead of an individual profile.[36]

5 | CONCLUSIONS

Work-related falls continue to represent a substantial burden of injuries. Multifaceted programs contribute to improving safety more than the sum of the individual components since each work setting is unique and requires a customized approach. AFSAS allows longitudinal quantification of the changes in injury frequency and demonstrates the value of safety program initiatives, especially for falls to a lower level. The emphasis of fall prevention efforts was on falls to a lower level, and the largest reduction occurred among falls to a lower level. Future prevention efforts to reduce falls should continue to focus on falls to a lower level and add emphasis on falls on the same level which account for more types of falls (albeit less severe). Future research should focus on more detailed trend analyses to understand the changes in risk among more refined groups (e.g., occupation groups) and directly compare fall injuries to all other types of injuries. Findings from this study contribute to the expanding body of knowledge on work-related fall prevention by providing valuable examples of fall prevention efforts, especially for workers in high-risk industries.

AUTHOR CONTRIBUTIONS

Christina Socias-Morales, James Collins, Bruce Burnham, and Cammie K. Chaumont Menéndez conceptualized the study. Christina Socias-Morales, Melody Gwilliam, Harold Gomes, and Bruce Burnham, were involved in acquisition, analysis, and data interpretation. Christina Socias-Morales, Melody Gwilliam, Harold Gomes, and Heidi Stallings were involved in drafting revisions in response to reviewer comments for the final review. All authors reviewed the analysis, contributed to drafting the manuscript, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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CONFLICTS OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are restricted from Air Force Safety Center. Privacy restrictions apply to the availability of these data, which were used under nondisclosure agreement for this study.

ETHICS STATEMENT

This activity was reviewed by CDC, deemed research not involving human subjects, and was conducted consistent with applicable federal law and CDC policy (see e.g., 45 C.F.R. part 46; 21 C.F.R. part 56; 42 U.S.C. §241(d), 5 U.S.C. §552a, 44 U.S.C. §3501 et seq.).

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, and Department of the Air Force. Citations to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date.

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ENDNOTE

* See e.g., 45 C.F.R. part 46; 21 C.F.R. part 56; 42 U.S.C. §241(d), 5 U.S.C. §552a, 44 U.S.C. §3501 et seq.

REFERENCES

1. Bureau of Labor Statistics (BLS). Census of Fatal Occupational Injuries (CFOI). Table 2. Fatal occupational injuries for selected events or exposures, 2017-21; 2022. https://www.bls.gov/news.release/cfoi.t02.htm
2. Bureau of Labor Statistics (BLS). Table 3. Survey of Occupational Injuries and Illnesses (SOII). Number of nonfatal occupational injuries and illnesses by selected industry and case types, private industry, 2019-21 (thousands); 2022. https://www.bls.gov/news.release/osh.t03.htm
3. Liberty Mutual Research Institute (LMRI). *2023 Workplace Safety Index* (Liberty Mutual Insurance, 2023). https://business.libertymutual.com/insights/2023-workplace-safety-index/
4. Socias-Morales CM, Chaumont Menéndez CK, Marsh SM. Fatal work-related falls in the United States, 2003-2014. *Am J Ind Med*. 2018;61(3):204-215.
5. Socias-Morales CM, Chaumont Menendez CK, Collins JW, Simeonov P, Centers for Disease Control and Prevention. Occupational ladder fall injuries—United States, 2011. *MMWR Morb Mortal Wkly Rep*. 2014;63(16):341-346.
6. Wang X, Largay JA, Dong XS. Fatal and nonfatal injuries among construction trades between 2003 and 2014. Center for Construction Research and Training (CPWR) Data Center; 2015. Accessed January 25, 2016. http://www.cpwr.com/publications/cpwr-quarterly-data-reports
7. Konda S, Tiesman HM, Reichard AA. Fatal traumatic brain injuries in the construction industry, 2003–2010. *Am J Ind Med*. 2016;59:212-220. doi:10.1002/ajim.22557
8. Tiesman HM, Konda S, Bell JL. The epidemiology of fatal occupational traumatic brain injury in the U.S. *Am J Prev Med*. 2011;41(1):61-67.
9. Anderson MK, Grier T, Canham-Chervak M, Bushman TT, Jones BH. Occupation and other risk factors for injury among enlisted U.S. Army Soldiers. *Public Health*. 2015;129(5):531-538. doi:10.1016/j.puhe.2015.02.003
10. Brooks RD, Grier T, Jones BH, Chervak MC. Activities and risk factors associated with fall-related injuries among US Army soldiers. *BMJ Military Health*. 2020;169:139-145. doi:10.1136/bmjmilitary-2020-001564
11. Patel AA, Hauret KG, Taylor BJ, Jones BH. Non-battle injuries among U.S. Army soldiers deployed to Afghanistan and Iraq, 2001-2013. *J Saf Res*. 2017;60:29-34.
12. Copley GB, Burnham BR, Shim MJ, Kemp PA. Using safety data to describe common injury-producing events. *Am J Prev Med*. 2010;38(1 suppl):S117-S125.
13. Canham-Chervak M, Cowan DN, Pollack KM, Jackson RR, Jones BH. Identification of fall prevention strategies for the military: a review of the literature. *Mil Med*. 2015;180(12):1225-1232.
14. Bunting J, Branche C, Trahan C, Goldenhar L. A national safety stand-down to reduce construction worker falls. *J Saf Res*. 2017;60:103-111.
15. Macario E, Hannon SW, Baker R, Branche CM, Trahan C. Preventing falls in residential construction: effectiveness of engaging partners for a national social marketing campaign. *Am J Ind Med*. 2015;58(8):809-823.
16. Huhman M. Bundled interventions. In: Thompson TL, ed. *Encyclopedia of Health Communication*. Vol 1-3. SAGE Publications, Inc.; 2014. doi:10.4135/9781483346427
17. Aboelela SW, Stone PW, Larson EL. Effectiveness of bundled behavioral interventions to control healthcare-associated infections: a systematic review of the literature. *J Hosp Infect*. 2007;66:101-108.
18. Pugh S, Chan F, Han S, et al. The impact of a nursing-led intervention bundle with a bedside checklist to reduce mortality during the initial COVID-19 pandemic and implications for future emergencies. *JONA*. 2023;53(5):292-298. doi:10.1097/NNA.0000000000001285
19. World Health Organization. *WHO Guideline on Health Workforce Development, Attraction, Recruitment And Retention in Rural and Remote Areas* (updated from 2010); 2021.
20. Occupational Safety and Health Administration (OSHA) Joint Stand-Down OSHA quick takes. https://www.osha.gov/as/opa/quicktakes/qt050815.html. Accessed January 7, 2016.
21. Department of the Air Force Manual 91-203. 03/25/2022. Chapter 13, Fall Protection. 101-108. https://static.e-publishing.af.mil/production/1/af_se/publication/dafman91-203/dafman91-203.pdf
22. U.S. Air Force Personnel Center (AFPC). Air Force Demographics; 2022. https://www.afpc.af.mil/About/Air-Force-Demographics/
23. Department of the Air Force (DAFI) NUMBER 36-2110. 10/5/2023. Total Force Assignments. https://static.e-publishing.af.mil/production/1/af_a1/publication/dafi36-2110/dafi36-2110.pdf
24. Department of Defense Instruction (DoDI) NUMBER 6055.07.08/31/2018. Mishap Notification, Investigation, Reporting, and Record Keeping. https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/605507p.pdf
25. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika*. 1986;73:13-22.
26. Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics*. 1986;42:121-130.
27. Pan W. Akaike's information criterion in generalized estimating equations. *Biometrics*. 2001;57:120-125.
28. Scott KA, Fisher GG, Barón AE, Tompa E, Stallones L, DiGuiseppi C. Same-level fall injuries in US workplaces by age group, gender, and industry. *Am J Ind Med*. 2018;61:111-119. doi:10.1002/ajim.22796
29. Bell JL, Collins JW, Wolf L, et al. Evaluation of a comprehensive slip, trip and fall prevention programme for hospital employees. *Ergonomics*. 2008;51:1906-1925.
30. Bell JL, Collins JW, Chiou S. Effectiveness of a no-cost-to-workers, slip-resistant footwear program for reducing slipping-related injuries in food service workers: a cluster randomized trial. *Scand J Work Environ Health*. 2019;45(2):194-202. doi:10.5271/sjweh.3790
31. Kaskutas V, Buckner-Petty S, Dale AM, Gaal J, Evanoff BA. Foremen's intervention to prevent falls and increase safety communication at residential construction sites. *Am J Ind Med*. 2016;59(10):823-831. doi:10.1002/ajim.22597
32. Jones BH, Canham-Chervak M, Canada S, Mitchener TA, Moore S. Medical surveillance of injuries in the U.S. military. *Am J Prev Med*. 2010;38(suppl 1):S42-S60.
33. Sundstrom JN, Webber BJ, Delclos GL, Herbold JR, Gimeno Ruiz de Porras D. Musculoskeletal injuries in US Air Force security forces, January 2009 to December 2018. *J Occup Environ Med*. 2021;63(8):673-678. doi:10.1097/jom.0000000000002207
34. Department of the Defense (DoD). Health of the Force; 2021. https://www.health.mil/Reference-Center/Technical-Documents/2022/12/14/DOD-Health-of-the-Force-2021
35. Song JW, Chung KC. Observational studies: cohort and case-control studies. *Plast Reconstr Surg*. 2010;126(6):2234-2242. doi:10.1097/PRS.0b013e3181f44abc
36. Walsh S, Wallace L, Kuhn I, et al. Population-level interventions for the primary prevention of dementia: a complex evidence review. *eClinicalMedicine*. 2024;70:102538. doi:10.1016/j.eclinm.2024.102538

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